AMERICAN

RAILROAD JOURNAL,

AND

MECHANICS' MAGAZINE.

No. 1, Vol. VI. New Series. | JANUARY 1, 1841. | Whole No. 373. Vol. XII.

At the commencement of another year of editorial duties we beg leave to offer our best wishes to our readers, together with our hearty thanks for past favors. In accordance with the intention of doing every thing in our power to improve the appearance and character of the Railroad Journal, the reader will perceive that this number appears in a new dress. The type does credit to the establishment of J. T. White, of this city. Although the expense incurred is great in proportion to the size of our establishment, we have not hesitated to make an improvement so conducive to the comfort of the reader and the satisfaction of our contributors. If the encouragement we have received is continued we shall not fail to increase our efforts to merit it by every exertion in our power.

The review of the last volume renders us sensible of the great favors we have received from our friends, by whose kindness we have been enabled to give on an average the half of each number in entirely original matter. The number of communications now on hand leads us to hope that there will be no falling off in this proportion.

The prosecution of internal improvements, of steam navigation and manufacture, being absolutely necessary to our existence as a commercial nation, insures a never failing supply of matters of interest and importance on subjects coming within the province of the Railroad Journal, and it is only necessary that those who are concerned should aid by their contributions to the maintenance of a work, which from its commencement has been identified with their interests.

The development of our national resources deserves a more attentive consideration than it has hitherto received from those en-

gaged in the cause of internal improvement. Our vast mineral wealth and the products of the soil, capable of almost indefinite increase, furnish us with the means of extending our internal and external trade far beyond the present limits even without any increase of population—while the recent census has shown the increase in that respect to be abundantly sufficient to support our railroads, canals, and steamboats—and that a further gain in the same proportion, will require a corresponding extension of the means of conveyance throughout the country.

For the American Rrailroad Journal and Mechanics' Magazine.

ON THE TRUE THEORY OF CRANK MOTION. By *W. Mc Clelland Cushman*, Civil Engineer.

It is, I believe, a settled maxim of science, that that theory must be wrong which disagrees with or does not explain the phenomena of experience. Yet I know of no extant theory of the crank which, when applied to the locomotive engine, does not totally fail to solve the actual loss of effect produced by the operation of the crank in those engines. *See note Vol. 4, p. 243.*

For instance, some have contended that more than 1 part in 5 of power, in these engines, is expended without any useful effect, exclusive of friction, etc. *Note* 1.

Others, again, that in general, no part of the power is lost in crank motion, except that caused by extra friction, etc. While, from whatever cause or causes arising, the fact is that rather less than 1 part in 16 of power, or accurately ·0583 of the powers of locomotive engines, is annulled or expressed without effect, through the operation of the crank. So that at all events, *the theory warranted by experience*, has yet to be disclosed.

This unsettled state of the mode of action of a mechanical arrangement of such universal use and importance in machinery, and particularly in the grander movements of the steam engine, after so long a period, it must be admitted affords very decisive proof of its abstruse character; but effects having adequate causes, and the crank being an assemblage of levers of determinate lengths—of use, solely, to change the alternate motion of the power into a rotary motion—the causes of any loss of power actually attending its operation are certainly susceptible of analysis; and the influence or efficacy of each of estimation a priori, etc. I cannot consequently apprehend any difficulty, of an insuperable nature at least, in the way of disclosing and confirming by facts drawn from experience, the general principle of action or theory of the crank: nor

of being able to fix upon the amount of power lost through its operation, under every circumstance of practice.

Now in crank motion (as indeed in all machinery) the effect producible by the moving power must always be modified or reduced by one or both of the following causes:

1. *Direct loss of power:* from its not being applicable *directly* to the end of the crank; but from the nature of things, *conveyed to it*, through the agency of a connecting rod, in lines *oblique to the fixed direction in which the power acts;* whereby certain components of the power itself are *compulsorily* expended in directions that cannot contribute to the effect which otherwise would be produced by the same expenditure of power. This fact alone, it will in the sequel be made to appear, originates the greater part of the actual loss of power attending the production of rotary motion by means of a crank.

2. *Indirect loss of power:* from the resistance of friction at rubbing points, opposing the motion in proportion to the pressure upon the surfaces in contact, their nature, etc.

The aggregate influence of each of these general causes is made up of several distinct items of loss taking place at different points. But before entering in the main into the question, it will perhaps be best to give a definite notion of what *really constitutes loss of power.*

For instance, it is true it is a necessary consequence of the laws of motion, that the pressure exerted upon the end of the crank of an engine *must*, at all events, be as much less than the power expended upon its pistons, as the velocity of the crank is greater than the velocity of the pistons; viz. in the ratio of half the circumference of the circle described by the end of the crank to its diameter, which corresponds to the length of stroke of the pistons. But the fact of the *pressure* upon the crank being so much less than the moving power by no means implies any loss of power, because, however much reduced, that pressure is exerted over a space just enough greater than that described by the power to yield, in the same time, the same total of effect as the power actuating the pistons yields. If, therefore, the nature of crank gearing were such as to convey the power of the pistons to the end of the crank (or indeed any other part of the machinery) without any further change than mere reduction of pressure inversely with the velocity of parts, it is clear that the use of the crank could not be attended with any non-effective expenditure of the moving power.

In further illustration of this point, put l for the length of stroke (=double the radius or throw of the crank); P for the power actu-

ating the pistons; p for the pressure upon the end of the crank; and π for the arc of the quadrant to radius 1. Then as from the nature of the connexion of parts, p must describe the space $2\pi l$ in the same time that P describes the space l, we should have $\frac{1}{l} : \frac{1}{2\pi l} :: P : p$ and consequently $p \cdot 2\pi l = P l$ which shows that the total effect produced by the pressure upon the crank, would in the case supposed, be perfectly identical with the total produced by the power expended upon the pistons.

An actual loss of power or effect can, then, have no reference to *mere reduction of pressure upon the crank*, in the ratio of its excess of velocity over that of the piston; but to some *further change* due the nature of the gearing, causing portions of the force to be expended non-effectively, in transitu, etc. leaving but a residuum of power actually operative upon the crank, less of course, in amount than that which has been represented by p.

So, in this case, (putting p' for the mean pressure actually effective upon the crank,) since the pressure upon it would be p in case no loss took place, we should evidently have $\frac{p'}{p}$ for the proportion of effect produced to power expended; and consequently

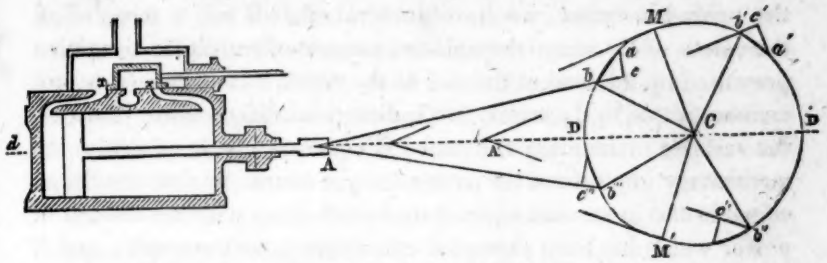
$$\frac{p'}{p} = \frac{p' \cdot 2\pi l}{p \cdot 2\pi l} = \frac{p' \cdot 2\pi l}{l \cdot P}.$$

and hence, if we compare, indifferently, either the actual pressure upon the crank with the pressure which would have been exerted upon it, did no loss exist; or, the moment of the actual pressure upon the crank with the moment of the power expended; we shall in either case obtain the true proportion of effect produced to power expended. Profiting accordingly by the liberty of choice in this respect to consult simplicity, I will, in the first instance, consider—

What amount of moment is regularly communicable from the pistons of an engine to the end of its crank, in the direction of its motion; and, afterwards, designate the proportion of power lost, by contrasting that result with the moment of the power expended, agreeably to the foregoing principles.

Let then A b, A′ b', etc. represent positions of the connecting rod corresponding with b C, b' C, etc. positions of the crank; d D D′ the fixed direction in which the force P, upon the pistons, alternates; and P′ for the proportion of P communicated to the connecting rod. Put also M, for the total moment communicated to the crank in the direction of its motion, during a complete revolution; r = A B, the length of connecting rod; l, as before = 2 · b C, double the throw of the crank or length of stroke of the pistons; and z any arc (to

radius 1,) corresponding with the angle made by the crank with D C, reckoning from D, either in the upper or lower half of the rotary circle. Further let *a b* represent the very small arc of the



rotary circle run over by the end of the crank in an indefinitely small space of time; *b c* its *projection* upon the connecting rod, the direction of the force P′; B = the angle included between *a b* and its projection *b c*; and *m* the angle included between *a b* and the direction of the motion of the crank, that is, between *a b* and the tangent at *b*.

Suppose now P′ the power communicated to the connecting rod, impress upon the end of the crank the very small motion *a b*, and R such variable resistance as would, if applied to the end of the crank directly in opposition to the motion of the crank, keep the force P′ in equilibrio. Then agreeably to mechanical principles, the moment of the virtual velocity of P′ is equal to the moment of the virtual velocity of R, or since *b c*, the projection of *a b* upon the direction of P′ is the virtual velocity of the former; and *b a* cos *m*, the projection *a b* upon the direction the resistance, that of the latter we should have

$$b c \cdot P' = b a \cos m \, R,$$

and consequently, since *b a* cos B = *b a* and cosine of the indefinitely small angle *m* is = 1,

$$b a . \cos B \cdot P' = b a \cdot R,$$

for the relations of the power and resistance which must subsist during a single impulse of the power, while the crank is running over the extremely small arc represented by *a b*.

Now a state of continued motion and of equilibrium, like that which actually subsists in practice, is nothing more than a continued succession of *impulses* similar to the above; and would evidently be resolved, when all the values which the equation of momentary equilibrium would give, during an infinite number of successive impulses of the power have been collected together. In my judgment, a problem of this nature must elude every other mode of investigation but that sketched in my previous communication, to which I have already alluded.

Our reasonings so far, have been with reference to *a b* as a very

small finite arc; but that arc is in fact, nothing else than the *differential* of z and we may accordingly write $dz \cos B \cdot P' = d z \cdot R$, instead of the last preceding equation. Taking the integral of the second member, we have integral of $dz\,R = z \times$ mean of all the values of $R \cdot = z \times$ the uniform amount of resistance to motion presented by the load at the end of the crank, $= z \times$ mean pressure communicated to the crank, in the direction of its motion. Because the variable momentary resistance R equilibrating continually the momentary impulses of the power does, of course, by that condition, coincide also in amount of resistance at all times with the amount of power which has been expended effectively upon the crank; and if it did not, periodically at least, and at furthest on the termination of each revolution of the crank, also afford a mean result agreeing precisely with that uniformly presented by the load moved; the velocity of the crank would be accelerated or retarded, indefinitely, instead of performing consecutive revolutions in equal times, which is the actual state of things. Accordingly we should have $\int dz\,R = z\,p'$ and consequently

$$\int dz \cos B\,P' = z\,p',$$

which shows that the integral of the first member of the equation of momentary equilibrium determines the amount of moment communicable from the pistons to the crank, etc. It is therefore only further requisite to settle the limits between which the same mean amount of moment will constantly be reproduced upon the crank, as would be produced during any number of revolutions, and intigrate this expression accordingly, in order to determine what amount of moment is regularly communicable from the pistons of an engine to the end of its crank, etc.

With this view let the mutations in the expression of the momentary effect be traced throughout the revolution of the crank. We see, for instance, that at the point D, the beginning of the forward stroke, $\cos B = \cos 90^\circ = 0$ indicating what is manifestly the fact, that in that position of the crank, the whole power is expended non-effectively. This is technically known as "a dead point." Tracing it onward it will be seen to increase continually with the advance of the piston, until arriving at the point M, where A B becomes tangent to the rotary circle, cos B becomes a maximum, to wit = 1, indicating that in that position P' has its greatest possible effect upon the crank, and the power consequently nearly fully effective. The magnitude of cos B decreases continually from this point onward, till arriving at D', we have again $\cos B = \cos 90^\circ = 0$, and the

power of course becomes a second time in the progress of the stroke entirely incapable of any useful effort. This is also a "dead point."

Hence it is clear that cos B may be expressed each way from the point of maximum to the terminal points of the stroke, by a single function of z and the data. But the projections of dz fall either within or without the rotary circle according as it is taken upon one or the other side of M; and from this circumstance take very different numerical values, in similar positions, upon either side of that point. Two functions, then, become requisite to express cos B while the crank is in the upper half of its revolution; and each of them of course requires separate intigration over the extent to which each function applies.

A similar series of mutations takes place on the return stroke of the piston, while the crank is performing the lower half of its revolution; and distinct functions are here required, since the projections of dz do not correspond in this half with those directly above; but, falling reverse ways in reference to the rotary circle, will be seen to have different values from those immediately above them. The two required have also to be integrated seperately over the extent to which each applies. The amount of effect produced then in the forward, is not exactly reproduced on the return stroke; nor is that produced forward of the points of maximum in either, reproduced in the after part of the stroke; so that it is impracticable to arrest the integration sooner than the close of a full revolution of the crank.

With regard to the immediate functions required, simple geometric relations give the following equivalents of the angle represented by B: viz.

1° for the arc D M, $(90-m)$—sup of sup $(z+A) = \text{co.}\, m-(z+A)=B.$

2° " M D′, $(90+m)-(\sup z-A) = m+(A-\text{co.}\, z)=B.$

3° " D′ M′, $(90-m)-\sup z-A) = -m+(A-\text{co.}\, z)=B.$

4° " M′ D, $-(90-m)+\sup (z+A) = m+(\text{co.}\, z-A)=B.$

So also with regard to P′, the revolution of P the power actuating the pistons into components along and at right angles to A B, gives P cos A = P′ for the variable proportion of the power actually communicated to the connecting rod.

See 34. P.

Note 1. The fact above mentioned proves the necessity of entirely new researches upon this subject; but it may be here noted, in passing, that, even allowing the state of things *assumed* by J. A. Roebling, (R. R. J. vol. 4, page 162.) to agree with that which *actually exists* wherever the crank is employed in connexion with the steam engine, it is still liable to this objection; the same process of reasoning he employs applied to his effective ordinate would give for the effect produced .2146; and thus we should have this remarkable state of things—to wit: but 1 part lost and 1 part effective out of 5 of power actually expended! or 4 parts lost and 4 parts effective out of 5 parts of power expended, each and all at one and the same time!

(To be continued.)

For the American Railroad Journal and Mechanics' Magazine.

The following graphic description of the *advantages of a railway compared even with a river, for transportation and travel* is the sober report, of "a joint special committee of the legislature of Massachusetts."

The period is near at hand, when our legislature should entertain the neglected subject of railways, and fix on some *system* by which the State and its treasury will not be cursed with unprofitable works, commenced and pursued with perseverance by designing politicians. I am gratified to find by your last number, that "*Fulton*" has thrown out a plan for consideration, which if adopted, will have one great advantage, and save the State millions on millions. I mean, the support by the State to *private enterprize*, where individuals show confidence in their own projects, by *first* disbursing their own means to the extent of two-thirds of the cost of the proposed work, to entitle the projectors of a railway, to a subscription risk by the State of one-third its cost. The State should appoint one-third of the directors; with this check, there will be no fear that their money will be squandered. Not so with works undertaken and managed by the State, or general government. Witness the Columbia-railroad in Pennsylvania, where 80 miles have cost upwards of four millions of dollars badly located, with inclined planes on a line, that will be superceeded by the Philadelphia and Reading railroad. The State furnish the *motive power*, on the Pennsylvania railroad, whilst individuals furnish the cars, and charge higher for transportation, than any railroad within the writer's knowledge in the United States.

As another instance of extravagant expenditure by the general government, look to the Cumberland or National road, abandoned by general consent, from its cost, government patronage, etc. etc. The ground is yet, almost too hallowed to touch on canals made by this State. This arises from our success with the Erie Canal, owing to its peculiar location, connecting as it does a rich State and inland seas with the ocean. The period, however, has arrived, to stop the extravagant expenditures in this State, on any new canals, and the sooner we razee the expenditure on the enlargement, untill sane men prove that it is needed by the present generation—the better it will be for our tax-paying proportion of the community. The Black River, Genesee, and Chenango canals, will share the fate of the Blackstone, Middlesex and Farmington. Railways will superceed them. J. E. B.

"Railways universally have created the means of their own sus-

tenance, and have drawn to their tracks employment for their motion. If the beneficence of Providence had hollowed a channel from our coast to the western lakes, and poured the floods of those inland seas eastward to the ocean, the blessings would have been too great for sufficient gratitude, as they would have been beyond all computation. The river, swelled by tributary streams from every valley, would have scattered wealth along its course. For all practical purposes, the invention of art bestows better advantages, and furnishes communication more easy and certain than the bounty of nature could give. During the stern winter of our climate, the rivers are closed for one-third of the year with ice; in summer, they are exhausted for a nearly equal period; their navigation is bounded by the hills that supply their fountains. The railroad is neither locked by cold, nor dried up by heat, nor confined by ridges. Stretching out its arms to every town and village, it may be extended beyond the highland barriers of water passage, and beyond the lakes, until its iron bands clasp together in a net-work of improvement overspreading the whole Union."

For the American Railroad Journal and Mechanics' Magazine.

PLAN FOR CONSTRUCTING RAILROADS. Proposed By *John A. Roebling*, Civil Engineer.

Fig. 1.

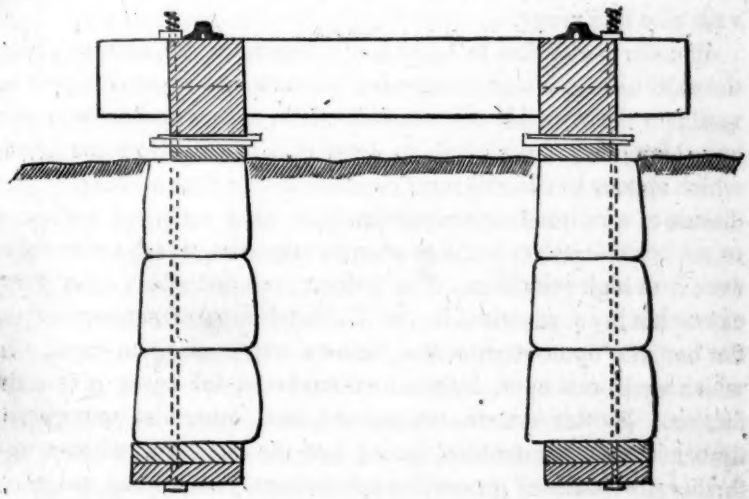
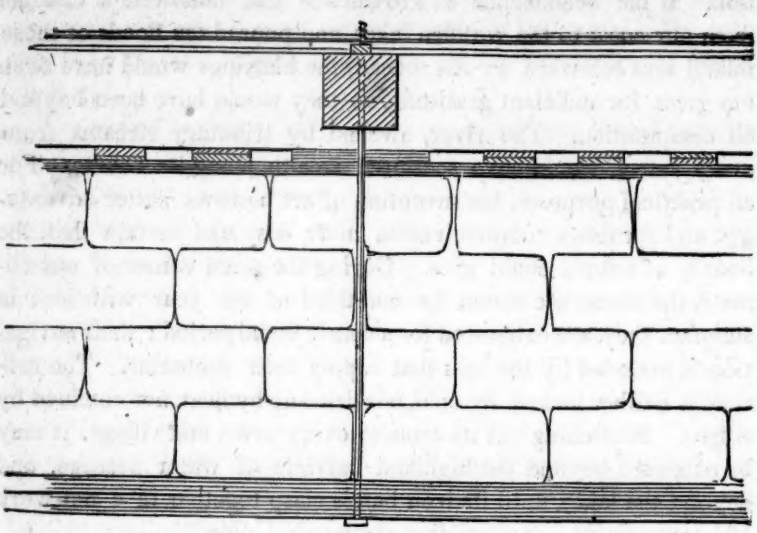


Fig. 2.



The friends of railroads are still in search of a mode of construction, which will form adequate tracks for the successful operation of our improved locomotives. Many plans have been tried and tested for years; none, however, appears to have succeeded so as to deserve a preference before all others. The same diversity of opinion, which exists here as to the best mode of construction, prevails also in Europe.

In order to be able to adapt a construction most successfully to the object, for which it is intended, it becomes first necessary to investigate the principle of its action. I do not pretend here to offer any thing new; I wish only to draw the attention to some points, which appear to deserve most consideration. One of the first conditions of a railroad superstructure is, to offer sufficient resistance to the vertical action of the ponderous machines, which are to move over it at high velocities. The ordinary mode, which to a great extent has been practised in the United States, of supporting the flat bar iron upon longitudinal timbers and these upon cross ties, which again rest upon longitudinal mud-sills, did never give satisfaction. By this system, unseasoned, and otherwise unprepared timber is in large quantities buried into the road-bed without any further provisions of preventing the timbers from settling irregularly, or from being upheaved by the frost. The timber is moreover placed in a situation which favors a speedy decay. Modifications of this plan have been tried with some better success, still they leave

much to improve yet. Stone block have also been used as foundations for continuous bearing timbers. This was evidently an improvement, but not sufficient. A favorite mode of superstructure for the T rail was and is yet, to support this rail by sleepers or crossties at intervals, and to rest the sleepers loosely upon mud-sills. This mode of construction appears to be the worst and weakest of all. The tolerable good success, which some of these roads have had, should not be attributed to the manner of supporting the rail, but the greater rigidity of the same, resulting from its improved form and increased weight. The facility of repairs in substituting new slippers in place of the old rotten ones, speaks in favor of this system; but the frequent necessity of such repairs is just one of its chief faults. While such a road is working, it is all the while making. On all these roads are the foundations which are either timber or stone, not laid deep enough to resist the action of the frost, nor are they sufficient when the road-bed is softened by incessant rains. Foundations of broken stone have to be made very thick, to be of any service, and then they do not offer a uniform support.

There is a difference of opinion with respect to the immediate support of the iron rail. Flat bars have been found too insufficient and are nearly abandoned. In speaking of rails therefore, we mean edge rails or bridge rails, of the different forms. A support of the iron rail is necessary. The nearer the supports are, the less the rail will deflect vertically. A continuous support will therefore be the best. The views of those Engineers who are still in favor of supports at intervals, are neither corroborated by experience nor theory. The best material for the immediate support of the iron rail appears to be that, which with the necessary solidity for supporting pressure, and stiffness, unites sufficient elasticity, to counteract the impetuous effect of the great vertical pressure and concussions of the heavy engines. Stone as immediate support is too rigid a material; it has too little elasticity and is too unyielding. Felt is therefore introduced between the chairs and stone blocks, where such are used. By far the best material appears to be wood, as intermedium between the iron rail and the stone foundation. Timber will therefore always form an important material in the construction of railroads, even where an abundance of the best stone blocks can be had. Not only the effect of the intermediate timber upon the foundation is advantageous, but all the railroad machinery will run easier on a rail, resting upon timber, than on one resting solely on stone. The tremulous motions and vibratory concussions will be less on a timber support than on a stone support.

Timber can be had in the United States cheap and in abundance. Not so in Europe, where iron is often substituted in its place. Here iron rails of less weight will suffice, if the continuous bearing timbers are strong enough.

The question now arises, when timber is used in the construction, at what place should it be applied in the greatest mass? In answer, it appears to me, that the continuous bearing should be made as strong and large sized, as timber can be had at *moderate prices.* The practice of using sawed scantling of 5 by 8 inches and the like for bearings, has every thing against it, and will always make an insufficient road, unless the iron rail is very heavy. How can we expect from such sticks, to support quietly the tremendous weight of a rapidly rolling engine of heavy character? It is impossible.

In order to support great concussion, we must offer a massy and compact resistance. Although a framing or connection of scantling may contain as much quantity as a single heavy timber, yet the latter will resist all shocks and concussions more successfully than the former, because in the single timber, the material is united, and resists in a mass; in a connection of scantling however, the upper timber has to bear the first effect of the concussion solely, and can only transmit them to the rest below.

This view will be made clearer by the following illustration: A strong man stretched upon a floor, may support an anvil on his chest, while iron is hammered on it with sledges. One single stroke with the sledge hammer, executed upon his bear chest, immediately, would break his bones. But through the medium of the heavy and massive anvil, he is enabled to support a succession of blows unhurt.

The same principle may be applied to railroads. A heavy piece of timber is required for the immediate support of the iron rail, in order to sustain the first effect of the concussions, produced by the engine, and to transfer them to the foundation less injuriously. Or the iron rail must be very heavy instead of the timber. But wood is cheaper than iron. Instead of increasing the weight of the iron rail a few pounds per yard, we may increase the size of the timber considerably, and preserve it too. Another important advantage of a heavy continuous bearing is, that the weight of the load, which rests on a single point of the rail, is distributed over a greater extent of foundation in consequence of the stiffness of the timber.

The means we use to support heavy masses, must be also massive in their nature, if they are to answer the purpose. The greatest resistance should be where the exposure is greatest. Now the lateral motions, which are produced upon the rails, are far less than the

vertical motions, less provisions are therefore required to counteract them. Heavy continuous bearing timbers of 12 inches by 15 inches, have in itself, lateral strength enough to require no more ties, than one of 12 inches square every ten feet. Thus the number of pices is reduced and the construction and repairs simplified.

By the old system of supporting the edge rail on a sleeper every 3 or 4 feet, the number of pieces is multiplied. There they are necessary to support the rails. This support extends however only to a little distance to the side of the rail, as the small dimensions of the ties will make them bend, if the foundation below the rail yields. Any timber therefore between the rails, that is not necessary for binding the track horizontally, is uselessly applied, as it will not serve as vertical support *efficiently.* The material for vertical support is most needed under the line of the rails, and outside of it *no more timber should be used than is required for lateral strength.*

The next important object is a proper foundation for the continuous bearing timbers. Nothing less appears to me to answer the purpose fully, than a regularly built dry wall, made of large stones with good beds. A stone filling between the rails or outside will not increase the vertical strength of the work, it can only prevent the lateral displacement. This however can be effected in another manner, as will be shown below.

The walls should extend 4 feet into the road-bed, so as to be below the reach of the frost or nearly so. They should rest on planks, which will prevent their settling unequally. Such provisions appear to be sufficient for the support of heavy loads.

But another effect of the railroad machinery upon the road has to be guarded against, and which is one of the most destructive in its consequences. This is the *recoiling* and *springing* of the superstructure, after the heavy weight, which depresses it, has passed over. Although this sinking and rising of the continuous bearing may be hardly perceptible at the commencement, it will increase and become a fruitful source of destruction in its consequences. A road may be perfect in all other respects, but if no provision is made, to prevent the rising of the construction, it will become deranged. But how is this to be avoided?

Mr. Brunel, it appers, was the first engineer, who has duly appreciated this great source of derangement and has on the great western railroad, in England, caused transom timbers to be bolted to piles, and which serve the double purpose of supporting the rail timber as well as prevent them from rising. The rail timbers are bolted upon the transoms, and the piles are driven deep

enough to resist the pressure from above as well as below. Although this plan serves the object for which it is intended, it will hardly be imitated in this country in all its features. The principles by which Mr. Brunel was guided in adopting that mode of construction, appear to be correct.

The object of securing the track downwards, may also be attained, by anchoring the wooden ties, which may be 10 feet apart, by means of iron rods, to the planks on which the walls rest. These anchors may be about one inch thick, round iron, have a head at the lower end and a good screwthread at the upper end. The wooden ties are then held down by means of plates and screw nuts. The rail timbers should not rest immediately on the walls, but on planks inserted between. Another space of two inches is then left between these planks and the rail timbers, which serves to drive in flat wooden wedges, for the purpose of forcing the rail timber up and the foundation down. The wedges are to be made of the hardest wood and driven in from both sides. The track can be very nicely adjusted by means of the wedges and screws. Thus the whole superstructure and walls are firmly united into one. The great weight of the mass will prevent all springing. The firm anchoring will also prevent lateral motions to a great extent. All future inequalities of the track are to be adjusted by screwing and wedging.

Diagram No. 1, at the head of this communication show the cross section of such a construction as proposed. Diagram 2 shows a side view.

The walls in the side view are assumed 4 feet deep, with a base of 21 inches, top 15 inches and a batter of three inches on each side. The foundation planks are laid double and 16 inches by 3 inches. About the anchors the best stones are used. In the first and fifth course the stones meet at the anchor, in the second and top course, grooves are cut in the stones to allow the free passage of the anchors. If not the whole of the timber is to be preserved, the foundation planks, which will be out of reach, should at least be secured from decay. The rail timbers are 15 inches by 12 inches. The cross-ties are supposed to be 10 feet apart from centre to centre and 12 inches square. The iron rails are of the bridge rail form, which suits this superstructure best. An improvement would be to screw straps of hard wood upon the rail timbers and fix the rails upon the straps, as is done on the great western railroad. If the iron rails are 20 feet long, the rail timbers should be either 20 or 30 feet long. Where two timbers meet, they are to be notched half their thickness, the notches for the intermediate cross ties, how-

ever should be only 4 inches deep. The upper corners of the rail timbers may be champered off. The heads of the anchors rest against a plate of sheet iron. Another plate is placed under the screw nut and so formed as to fit on one side upon the web of the iron rail. The bridge rail is firmly fixed *in its middle* by two screws upon the rail timbers, and not upon the cross tie, where two timbers meet, so, that a screw is driven in each end of a timber a few inches off the tie. The other extent of the iron rail is secured upon the timber by spikes or screws so that the iron is allowed to expand and contract. The same plate which is laid under the screw nut of the middle anchor, supports also the rail ends. This plate may be cast with 3 projections. One projection in the middle serves for the purpose of fitting in the grooves of the rail ends, and thus securing them laterally. The others serve to confine the web of the rails. This plate is let into the wood. The screw plate of the anchor holds the webs of the rail ends down on one side, and on the other side two other screws or spikes are driven. Thus the rail ends are sufficiently secured.

On embankments the anchor screws should be made long enough so that the rail timbers can be raised to the proper level, after the embankment has become solid. Another course of stone or timber is then to be placed upon the wall under the rail timber. Where the road-bed is formed in excavation of a slaty and porous nature, there it may not be necessary to sink the walls 4 feet low, as such a road will be naturally dry and not much effected by frost. The forming of ditches for walls in solid excavation would be too expensive. In that case I would recommend neither walls nor anchors, but a coupled rail timber in place of a single one, resting loosely upon the solid road-bed. A stone filling would in such a case be necessary to prevent lateral displacement.

Where the walls are sunk low enough and the anchoring is firm, a stone filling between the rails appears unnecessary. The superstructure and the walls will be so strongly united, that the great friction will prevent any lateral displacement. If a stone filling or ballasting should be found advisable, it should not be put in before the whole work is settled and re-adjusted. The wedging could afterwards be only performed from outside.

The last adjustment should be effected in the following manner. A locomotive of the heaviest class is run upon the road and its weight upon the driving wheels increased one half at least. This can be done by throwing the weight of the tender on it, and by loading the platform before the fire box with additional weight. While

this heavy load rests upon the rails exactly over a tie, the anchor screws are drawn tight, if the rails are too high. While this engine is running slowly back and forward over a short extent of the road, it is observed, if the rails are depressed or remain firm. By alternate tightening or easing the wedges and screws, the whole construction will be forced into a compact union, which cannot be seriously effected by any future action of the locomotives.

If so adjusted and strengthened, it may reasonably be expected, that such a road will present a perfectly smooth and regular track, on which the railroad machinery will ply in the easiest manner and without any jolting and jerking whatever. It is even thought that the firm anchoring will not admit any derangement by the frost. A slight re-adjustment, however, in the spring of the year by tightening the wedges, will be attended with little cost.

The above plan is not suggested with the idea of offering any thing like perfect. I wish it to be considered merely as a contribution to the general stock of practical means and ways already in use.

The great objection to such a construction will be its cost. But since we cannot form a good substantial road without great cost, it will be good economy to go to a heavy expense at once at the first outset, and avoid endless repairs in the future. Such a road will then be found the cheapest in the end.

Would it not be better, instead of grading roads for a double track, where there is not sufficient business to be expected the first 20 years for a well managed single track, to form the bed only for one track with suitable turn-outs, and to expend the money, thus saved, upon a good superstructure?

Paradoxical as it may appear, it can be practically demonstrated, that *with a moderate business*, a single track, well regulated and managed, will afford as much safety as a double track. A single track, when managed improperly, will not work at all. Therefore a thorough going system is indispensably necessary; and if adhered to at all times, it will fulfil all the conditions of a second track.

For the American Railroad Journal and Mechanics' Magazine.

THE LAWS OF TRADE APPLIED TO THE DETERMINATION OF THE MOST ADVANTAGEOUS FARE FOR PASSENGERS ON RAILROADS. By *Charles Ellet, Jr. Esq.*, Civil Engineer.

If any explanation were needed for the publication of this paper, it is probable that a sufficient one might be offered in the fact that the railroads now constructed, and in progress of construction, in this country, will cost from two to three hundred millions of dollars; and that the tariff of char-

ges are nearly always the result of the most vague conjecture, and frequently such as greatly to reduce the revenue which they might be made to yield.

The writer has elsewhere exposed the incorrectness of the present method of assessing the charges on heavy tonnage, and endeavored to offer the means by which, it is believed, the proper rates may, on that part of the business of the work, be determined with great certainty. The present paper is intended to extend the application of the same principles to the matter of fares for passengers on railroads; a question which is equally susceptible of being subjected to a process of accurate reasoning, and which furnishes equally correct premises for the foundation of the argument. And if these premises have been justly assumed, and the conclusions fairly deduced, it may be averred, without risk of exaggeration, that the neglect of the results obtained from them, induces a loss to the proprietors of the railroads in this country alone, amounting annually to several millions of dollars.

The establishment of the tariff for an important improvement, is a momentous question for the company; and one which requires as careful an investigation of the facts, and the exercise of as much sound judgment, as any other which the engineer is likely to encounter in the course of his professional practice. The most consummate skill may be applied in the location and construction of the work and its appendages, and the entire success of the enterprise may still be marred by the subsequent injudicious administration of its affairs.

But it is not for the computation of the charges only that an attention to the requirements of the laws of trade is essential to the prosperity of the undertaking. In deciding on the character and location of the work, and adopting a system of transportation, it is equally imperative. It is as impossible to select the most appropriate plan of construction, and make choice of the most advantageous location, without a proper regard to the amount and nature of the business to be transacted, as it is to assess the charges without an attention to the cost of freight, and the value of the article to be conveyed. A road intended for the accommodation of a trade of 100,000 tons, or passengers, will generally be placed on very different ground, and ought always to be built in an entirely different manner, from those which would be adopted if a trade of but 10,000 tons were anticipated. In both cases, the inequalities of the natural surface must be more or less removed, for the purpose of reducing the expense of transportation; but the outlay justifiable for this object is wholly governed by the value of the object, which is dependent on the amount of trade. The heavy excavations and embankments are made for the purpose of reducing the price of freight; and if the trade be 100,000 tons, it will be worth 100,000 cents, or 1000 dollars, per mile per annum, to reduce the cost of transportation one cent per ton per mile. This sum is equivalent to a capital of some 16,000 dollars—the expense which might be incurred on each mile of a

road of such expectations, in order to reduce the freight the amount designated. But if the trade is to be only 10,000 tons, the same object, by this reasoning, would only justify an outlay of about 1,600 dollars; and consequently the road intended for the light trade would, of necessity, be placed on very different ground from that which would be chosen for the other.

The outlay should never be more than commensurate with the object for which it is incurred; and therefore, the first and most important data to be plovided by the engineer, in the incipiency of the enterprise placed under his professional guidance are, the value of the object contemplated by the undertaking—the amount of the trade expected to be accommodated—and the extent of its dependence on the arrangement which he dictates; data which can only be obtained and appreciated by an attention to the laws to which the trade is subject.

The prosecution of these considerations will lead at once to the conclusion, that incalculable sums of money have been sunk on the improvements of this country, in reducing the irregularities of surface on works of small pretensions. That on such roads the grades ought to be comparatively steep; tunnels, deep cuts, and all similar expensive works should be avoided; and the hills and valleys, for the passage of which they ase designed, should be crossed by increasing the acclivity of the grades and the length of the line. The superstructure, also, both of wood and iron, as well as the location, should be adapted to the trade; and the dimensions and weight of the engines and cars should be governed by the same considerations, and adapted to the intention of the road, and the character of its superstructure.

If the trade be great, the road must be made to correspond with it; and the foundation may then be immovable; the rails of iron, the track of great width, the acclivities gentle, the velocity slow, and the weight and power of the engines adequate to the movement of the heaviest trains. In the former case, the size of the engine might be limited to two or three tons; and in the latter, it may be extended to twenty or thirty. The cars on the light road may be made for the accommodation of eight or ten passengers; and on the other, if we choose, they may resemble moving palaces, and be provided with almost all their comforts.

All the arrangements must be subject to the control of the real or anticipated trade; and the character of the work, as well as the administration of the affairs of the line, must depend on the application of the principles which we have attempted to develope under the appellation of the "Laws of Trade." Our present study relates to the latter department—the administration of the line, in reference to the question of

The Fare for Passengers on Railroads.

The principles which have served for a guide to the results announced in the preceding articles, are not less useful in the determination of the charges proper to be levied on railroad passengers. There are, however, difficulties to be encountered in this division of the subject, which do not

always obtain in the discussion of the laws which govern the trade in heavy commodities of small value, previously considered; and which, though they cannot be thought to leave the general results at all exceptionable may render the employment of the formulæ embarrassing in some particular applications. But yet, it is believed that by the division of the whole subject between the question which has for its object the calculation of the charges proper for particular lines, connecting important places, and the wider problem, to determine what should be the fares common to several connected railroads, that their aggregate net revenue may be the greatest possible—it will be relieved of many of its difficulties.

In reflecting on this problem, the first inquiry which presents itself is, what are the circumstances which govern an individual in deciding on the propriety of undertaking a journey? for if there be no law to which his decision is subject, there can be none to govern the charges exacted for his conveyance. But, fortunately for our purpose, there is one very important consideration which, in this commercial age, appears to control all the enterprises of man in civilized society, and to the application of which there can be no exception made in favor of his travelling propensities. This is the consideration of *cost, or hope of gain.* The profits of business, curiosity, or the prospect of pleasure, incites to embark on the voyage; and the *cost of the journey*, whether it consists of the value of his time, the importance of his personal attention to his home affairs, the desire to yield to the dictates of indolence, or the amount of his travelling expenses, urges the party to remain. He reflects on these opposite considerations, and forms his conclusions; and the result is, with very few exceptions, that he cannot afford to set out if the cost of stage *fares* will exceed a given sum. They who are to transport him have no control over any item which enters into his computation of the cost, but this; he puts his own estimate on the value of all the other considerations, and balances the account as his judgment and feelings admonish. And his final conclusion depends on the comparison of the sum which he thinks he can afford to pay for his fare, with that which the companies are disposed to exact. It matters not, for our present purpose, what this limit, which he chooses to prescribe for himself, may be—whether it amount to one dollar, or to twenty dollars—providing it be admitted that there is a sum to which each individual, after considering all the circumstances—all the charges—the advantages sought, and the inconveniences to which he will be exposed, limits the amount that he will rather pay for his fare than decline the trip.

An individual thus situated is in precisely the same condition with reference to the proposed excursion, as an article of merchandize in which he trades; there is a certain sum which may be charged for his conveyance without excluding him from the route; he will go if he is charged no more than that sum, and if charged more he will remain;—just as he will send his corn and lumber to market, if the charge for their conveyance will authorize him to do it, or retain them in his warehouse or in his for

est, if the charge be higher than he can afford to pay. He makes the same sort of calculation with reference to his journey as that which he institutes in deciding on the propriety of shipping his goods.

And if we were now able to separate the public into classes, and fix appropriate values on these classes, to represent the charges which they could afford to pay—as we can separate and value the different varieties of tonnage—the problem would be readily solved; for we would have then only to apply the equations already deduced for heavy tonnage,* to each class, by inserting in the formulæ the ascertained values of π, and obtain from them as many correct results as we should find varieties in the travelling community. But in the present case, we cannot proceed in this way, since we are compelled, by the constitution of society, to charge all—or at least all who receive the same accommodation—alike; and consequently, before the formulæ could be employed, it would be incumbent on the company to find, among all these infinite grades, that one which, if made the basis of the tariff, would yield the highest revenue. The company do not, however, know whether the value which represents this particular grade is a constant quantity, or whether, as appears probable, it may not be a function of the distance, or otherwise complicated.

To avoid these difficulties it will be necessary to pursue a different route; and assume, as authorised by the preceding remarks, that in every town on the line, or in every square mile of the country, there is a certain number of persons who can afford to make an excursion to some given point on the railroad—as the great city from which it issues—providing the cost of the trip shall not exceed a given sum. That there is another number that can afford to pay twice that amount—others three times that sum, and so on, until we arrive at the limit which would almost preclude travelling. We will also assume that the number of individuals in each of these classes is the same; or that there are three times as many who cannot afford to pay three dollars as there are of those who are unable to pay one—the number of persons excluded being directly as the sum which represents their grade; or, it may be assumed that for every increase of the cost of reaching the point in question, the number of passengers will be diminished; and that the diminution of the number will be proportional to the augmentation of the cost.

The investigation, based on these premises, will embrace two distinct cases, which appear to be the most important that are likely to be encountered in the course of the application of the principles to practical purposes. The business of the line will be assumed to be constituted either of the travel which proceeds from the large cities on the route, and which usually form the termini of the works of the separate companies; or of that which is thrown upon the main trunk by tributaries of greater or less consequence.

* Essay on the Laws of Trade, p. 63—5.

This discrimination is prompted by the consideration that it would seem proper for the separate companies to regulate the charges to be exacted of those who traverse their respective lines only; but that the rates to be levied on the distant traveller, who purchases his ticket and pays his fare "through," should be adjusted by the co-operation of all the parties. And the questions proposed for solution are: 1st. To determine the proper charges to be exacted of those who proceed from the cities on the line of the road, and who, for the most part, will pay over one line only; and 2d. To ascertain the law which should govern the prices to be paid by passengers who are brought to the principal route by its tributaries. These questions are too complicated to be treated without the aid of mathematical formulæ, and we will therefore designate by

π the greatest charge for conveyance which any grade of passengers can afford to pay;

$\mathfrak{C}$ the gross charge per mile on the railroad;

δ the freight or actual expenses per mile per passenger on the railroad;

c the toll or clear profit per mile per passenger on the railroad;

β the charge for conveyance, per mile, on the tributary;

h the distance from the assumed origin to the tributary.

Now, it is obviously proper to assume that if the fare on the road connecting two cities, as Philadelphia and Baltimore, were reduced to zero, and the public were carried free of charge, the number of travellers passing over the road, exclusive of those brought to the line by tributaries, would be some constant quantity, T; and it has already been assumed that for every increase of one cent in the charge, the number would be reduced some quantity represented by the co-efficient, t. The whole number of passengers proceeding from these cities will then be expressed by the equation.

$$T - \mathfrak{C}\, h\, t; \qquad (1)$$

since $\mathfrak{C}\, h$ is the gross charge between the two places. The clear profit which will be derived from the transportation of this number of persons will then be represented by

$$(T - \mathfrak{C}\, h\, t)\, c\, h;$$

a quantity which will attain its maximum value when the condition imposed by the equation.

$$c\, h = \frac{1}{2}\left(\frac{T}{t} - \delta\, h\right). \qquad (2)$$

expressing the charge on each passenger, exclusive of the actual expenses, is fully satisfied.

If to this quantity we add the actual expenses, $\delta\, h$, we shall obtain for the proper value of the gross charge.

$$\mathfrak{C}\, h = \frac{1}{2}\left(\frac{T}{t} + \delta\, h\right). \qquad (3)$$

From which we conclude that under the circumstances assumed, the gross charge which will yield the highest revenues on all the travellers

who pass between the two cities, at which they reside, will be obtained by *adding half the actual expenses to a certain constant quantity.*

The value of this quantity can readily be obtained by experiment. For this purpose we are to note the reduction of the number of passengers produced by any augmentation of the fare; from which we derive, by supposing the increase or decrease of travel proportional to the variation of the charges, the reduction caused by the whole charge $\epsilon' h$. This reduction, added to the number actually obtained under that fare, will produce the value of T; and consequently of the fraction $\frac{T}{t}$.

Now, the only objection to this argument is the assumption that the diminution of travel is proportional to the elevation of the charges on the line; a postulate which cannot be proved to be correct.

Indeed, it is probable that a given variation of the charge would produce very different values for the co-efficient t, at the extreme limits of the sums designating the elevations of the grades. But it is to be recollected that the equation can never be applied at these limits; since in practice the charges can never descend as low as δh, or the actual expense of conveyance, nor ascend as high as the sum which would justify the establishment of a rival. The space through which the charge can possible range, is confined within certain bounds, not very well defined, it is true, but still, sufficiently restricted to destroy the chance of any material error arising from this source. And consequently within these bounds it appears safe to assume that the *increase* or *decrease* of travel (not the travel) will be proportional to the elevation or depression of the charges.

According to the form of equation (1) there is a certain charge for conveyance so high that, if exacted, passengers would be entirely excluded, and we should therefore have, $T - \epsilon h t = o$; from which would be immediately deduced $\frac{T}{t} = \varpi$, the value of the highest grade in the community.

In fixing on the sum which represents the ability of this highest grade, if we choose to make use of this expression, we should not, of course, be governed by the occasional passenger whose wealth will authorize him to pay almost any sum for the gratification of his fancy. The expression cannot be extended beyond the class of which the number is sufficient to contribute materially to the support of the work. It is not, however, essential to the attainment of the greatest income that the determination of this point should be very accurate; and for the object now in view—the discovery of the proper method of graduating the tariff—it is a matter of still less consequence.

In passing to the second, and more important, problem which we have proposed to investigate, we will assume that when the charges for fare both on the main line and its tributary, are zero, the number of passengers received from each mile of the latter will be represented by any constan

quantity T; and that for every increase of the whole cost of conveyance to the place of destination, amounting to a unit of price, the number of passengers will be diminished the quantity t; we shall then have, for the reduction of the number of passengers furnished by any increment of space dx, situated at the distance x from the main line, due to a charge ϵ per mile for fare on the railroad, and β on the tributary,

$$(\epsilon h + x\beta)\, t\, dx;$$

and, consequently, for the differential of the whole number supplied by the tributary, the expression

$$dN = T\, dx - (\epsilon h + x\beta)\, t\, dx.$$

The intergral of this expression will represent the whole number of passengers, of every grade, supplied by the space consisting of x miles, measured from the main line along the tributary; and we shall therefore obtain by performing the integration, for the value of this quantity

$$N = Tx - \left(\epsilon h x + \beta \frac{x^2}{2}\right) t. \qquad (4)$$

Now, the highest grade of passengers supposed to come on the work by the branch in question, as we have already seen, is $\pi = \frac{T}{t}$; or the grade which renders the quantity $T - \pi' t$ equal to zero. And if we deduct from this value of π, the whole charge for conveyance on the main line, the remainder, $\frac{T}{t} - \epsilon h$ will stand for the sum that the portion of the community represented by π can afford to pay for conveyance on the tributary after paying the charge on the main line.

The distance which this grade can afford to travel on the tributary, will be represented by the quotient obtained in dividing this sum by the charge per mile for conveyance on the tributary—a quotient which is expressed by the equation

$$\frac{\frac{T}{t} - \epsilon h}{\beta} = x.$$

If we now substitute this value of x in the above value of the number of passengers furnished by the tributary, we shall obtain the new equation

$$\frac{T^2}{2\beta t} - \frac{\epsilon h T}{\beta} + \frac{\epsilon^2 h^2 t}{2\beta} = N, \qquad (5)$$

relieved of the quantity x, and completely expressing the number of travellers of all grades, destined to the assumed origin, thrown upon the railroad by the tributary under consideration. And if we now multiply this quantity by c, the toll or clear profit per mile, and substitute $\delta + c$ in place of ϵ,—differentiate the expression, and place it, as required by the rule, equal to zero, we shall arrive at the condition represented by the equation

$$\frac{T^2}{3h^2t^2} - \frac{2T\delta}{3ht} + \frac{\delta^2}{3} = \left(\frac{4T}{3ht} - \frac{4\delta}{3}\right)c - c^2.$$

This is a quadratic equation, from which we obtain, after clearing it of the radical, for the toll or clear profit to be derived from each passenger,

$$C\,h = \frac{1}{3}\left(\frac{T}{t} - h\delta\right); \qquad (6)$$

where the charge is understood to apply to the whole distance h, through which the passenger is carried. By adding to this quantity $\delta\,h$, or the actual expense of conveyance by railroad, we shall obtain,

$$\mathcal{C}'\,h = \frac{1}{3}\left(\frac{T}{t} + {}^{2}h\delta\right) \qquad (7)$$

for the gross charge which should be levied in order to obtain the highest dividend; an equation which again shows that *the whole charge which should be exacted of any passenger is a constant quantity augmented by two-thirds the actual expense of his conveyance.*

Although there are numerous subordinate questions connected with this problem, the two cases now examined cover the most important that can arise in the application of these principles to practical purposes. The equations resulting from the first will aid to frame the tariff on separate lines; while those of the second may be applied to lines of greater length, and constituted of a number of distinct interests.

It is not, however, necessary to make this distinction, unless there be sufficient reason to believe that the values of the fraction $\frac{T}{t}$ differ essentially for the two classes of travellers. This will be made manifest on a comparison of equations, (2) and (3) with (6) and (7); for we find by these expressions that both the toll and gross charge obtained for the two cases are of the same form, though differing slightly in value: and that the amount of this difference is but one-sixth the whole charge—a sum entirely too trifling too produce any appreciable effect on the revenue of the work. It is not pretended here to obtain the exact charge which would yield the highest dividend, within ten or fifteen per cent.; but it is the object to point out a method by which to avoid the common errors of such tariffs—errors which are not unfrequently five, and indeed much oftener more than ten times that amount. The loss of revenue may be wholly imperceptible when the deviation from the true charge is ten per cent.; but it must be remembered that for every dollar that is lost, on heavy tonnage, by an over-charge, or an under-charge of ten per cent., there will be experienced a loss of one hundred dollars for ten times that deviation. *The loss increases as the square of the departure from the charge which corresponds with the maximum revenue.** It is not essential to hit the exact mark, but it is exceedingly dangerous—certain indeed to be followed by great loss—to deviate too wide from it.

Such are the equations for the computation of the rates which must be

* *Essay on the Laws of Trade*, p. 152.—The increase is not so rapid in the present case, but it is still very great indeed.

established when it is determined to enforce in practice a rigid adherence to the principles which have governed the investigation. But, before proposing a rule for general usage, it will be proper to notice a modification which may be made in the formulæ, and ascertain the probable consequences of its adoption. Occasion has already been found in the course of these articles, to advert to that peculiarity of quantities which have attained a maximum or minimum limit, of being very slightly effected by a considerable increase or diminution of the value of the variable. In the question under discussion the variable which affects the amount of the revenue is the charge for toll; and, in consequence of this property, if we increase that quantity, as determined by the calculation now offered, any small amount, although the number of passengers, of the grades that are influenced by their travelling expenses, will be simultaneously reduced, the additional tax levied on the remainder will be almost sufficient to compensate for the loss due to the decrease of the number. Now, the whole charge for toll is

$$\frac{\pi}{3} - \frac{h\delta}{3};$$

and if we observe the form of this quantity, we will perceive that an increase of this charge equal to the second member, $\frac{h\delta}{3}$, would amount for any distance over which it would be possible, or desirable, to enter into a general arrangement, to a sum too small to produce any sensible reduction of the revenue. If, for instance, we assume six dollars for the value of $\frac{\pi'}{3}$ one cent per mile for that of δ, and 500 miles for the distance h—which last assumption is nearly equivalent to supposing that the arrangement is adopted by all the companies between New York and Raleigh, N. C.,—the effect of increasing the charge per passenger as suggested, the exact value of $\frac{\delta h}{3}$, would be to increase the net income per passenger, or charge for toll at that distance, but 37½ per cent.; while it has been shown that an increase much greater than this amount, on heavy tonnage, (Art. 2,) would not essentially reduce the revenue,—and at 300 miles the increase would be but 20 per cent., and the diminution of revenue nearly imperceptible.

We would, therefore, be authorized in permitting such a departure from the formulæ by these considerations alone, if there existed no other argument in its favor; but it will be observed that the equation (6) was deduced in the hypothesis that every individual using the line is more or less affected by the charges; an assumption which, although in this country almost universally true, is not without exceptions—for it must be admitted that there is a portion, though a very small part, of the travelling community, scarcely influenced at all by this consideration. We have not the

means of estimating the actual or comparative number belonging to this class; but there is cause to believe that the proportion which it bears to the whole number of persons travelling increases materially with the increase of distance. We also know that the effect of this modicum, if taken into the account, would be to augment the charge for toll; and, consequently, if allowed for in the above expression of the net income per passenger, that equation would assume the form

$$C\,h = \frac{\pi}{3} + f\,h = \frac{\delta h}{3};$$

in which, as before observed, we neither know the form nor the exact value of the junction $f\,h$—nor whether it be greater or less than $\frac{\delta\,\pi}{3}$ — though we do know that these quantities, besides being of opposite signs, are both too small to have any serious effect on the revenue. This sum might even be a positive quantity; but for reasons already adduced in justification of the neglect of $\frac{\delta\,h}{3}$, unless that positive quantity were one of very considerable importance, and much greater than the negative quantity $\frac{\delta\,h}{3}$, its neglect would have no visible influence on the revenue. We will, therefore be authorised to regard these quantities as very nearly equal; and consequently neutralizing each other. The preceding equations (6) and (7) will then become

$$C\,h = \frac{\pi}{3} \qquad (8)$$

for the value of the toll, or clear profit, per passenger, and

$$\mathfrak{C}'\,h = \frac{\pi}{3} + \delta\,h, \qquad (9)$$

for the gross charge for conveyance.

The rule which should be proposed for computing the tariff, will be drawn from the formulæ as modified by these considerations, and it may be expressed in few words—*add to the constant quantity which experiment dictates for the profit per passenger, the actual cost of his transportation* —to obtain the gross charge to be exacted for his conveyance.

The objection which may be urged against the importance of these equations, on the ground of the uncertainty which must attend any attempt to determine a priori the exact value of the constant quantity which enters them, is without force. It would be idle to expect any solution of the problem which would entirely dispense with the exercise of a discriminating judgment, or deprive experience of its usefulness. The formulæ teach us the law by which the charge must vary as the distance increases—and the only unknown quantity may be accurately determined by one or two judicious trials; without their assistance years of experience and the most accurate observation, will still leave the subject involved in the greatest uncertainty.

It will readily be perceived that, by the principles here advocated, there may sometimes be good policy in making a distinction between the different grades of travellers carried on the road; and in adapting the rates levied upon each grade to its actual ability. But, it is probable that such distinctions would be found productive of inconvenience sufficient in this country, to limit them to two classes—the first consisting of those who regard *cheapness* as more important than the superior comforts and more select society offered in the better class of cars, and the second, of those who are willing to pay something for these considerations. But the principles already announced for the assessment of the charges will be applicable to both these divisions;—they will each be required to pay, besides the actual cost of their conveyance, a certain tax, proportional to their respective ability, to go towards the profit of the company; and though the former part of the charge will vary with the distance, the latter part will be the same, whether the visitor to New York take the line at Baltimore, Richmond or Raleigh. The utility of such discriminations is, however, very doubtful unless made with a full appreciation of all the circumstances.

It need scarcely be said, that in fixing the charges for a long route made up of several distinct interests, an agreement between the companies composing it, to prevent injustice from being done to either, is an assumed condition. The method proposed aims for the maximum *aggregate* net income; the equitable distribution of the proceeds among the companies, will involve no difficulty, for the profits of any one line, derived from individuals who pay their fare over that line only, will, of course, belong exclusively to that company; but the profits obtained from tickets over two or more lines, will be divided among the several companies in proportion to the number of miles of travel on them respectively.

It may also be observed that the application of the system is not to be extended to roads so short that the quantity representing the profits would be such as to justify the establishment of a rival. The actual value of this constant must first be ascertained and applied to the distant travel; and if it amount to a higher sum than it would be deemed advisable to charge on the separate roads, or than their charters would permit them to exact, they would be at liberty to make the needful modifications. The regulations adopted on the lines taken separately, would be independent of those which would be applicable to the common interest.

It is not denied that there are plausible objections to the process which has conducted to the conclusions presented in this paper; and that it may not possess all the accuracy that is sometimes attainable in similar researches. But it does, nevertheless, seem to be the nearest approach to a rigorous solution of which the important, but complicated, problem is really susceptible.

Withal, the simplicity of the result adapts it peculiarly for general use and renders its application exceedingly easy on the longest and most complicated lines. It is offered as an attempt to elucidate a subject which

seems not yet to have occupied the attention of the profession, or of railroad companies—but which possess the highest interest, both as a question of profit, affecting the dividends due to the greatest investment of capital ever made for any one object of public improvement; and as a question of political economy, involving the measure of the benefit to be derived from the railroad system.

Wilkinson's Press.—It has long been a desideratum to obtain a rotary printing press; and although several have been invented upon the rotary principle, none has yet succeeded in adaptation to newspaper printing, nor we believe to book printing, other than stereotype. Mr. Wilkinson has devoted much time to this subject. and has at length constructed a machine, which not only overcomes the objections that have prevented the success of other machines, but which appears, in every desirable quality, to be superior to any press in use. In rapidity, accuracy, cheapness, both of construction and of running, it is believed to be unrivalled, and if it works as well as it certainly promises to, we do not see but it will effect a revolution in the art.

This press is capable, with less than one horse power, of throwing off twenty thousand impression an hour, printed on both sides. The types are set with the same facility as those in common use, and the contrivances for taking the proofs, placing the matter on the cylinders on the press, are such that all the operations can be performed as rapidly and as easily as with the ordinary types and presses. One boy can attend the machine with perfect ease. The machine is about six feet long, four feet high, and of any required width; it can be made, we should judge, for about a thousand dollars.

Notwithstanding the almost incredible power of this press, it is simpler in its construction than any power press in use; and herein is its great beauty. There are less than twenty wheels to drive the whole, and but *one* stud (or unnecessary wheel, employed to connect the parts, without driving any thing itself.) This does not belong to the machine proper, but connects it with the shears which cut the sheets off; for the paper is not cut into sheets previous to being printed, but is placed upon the machine in rolls. The shears cut it not quite in two, leaving sufficient tenacity for it to roll up, but dividing it so far that it will easily separate by a slight jerk. A register is attached which, counts the sheets as they come off.

The impression is as good as can be obtained on any press, and the types are less liable to wear, or rather they wear uniformly, not battering the edges. The machine now in operation will print three columns of the width of the Journal, and four inches longer. The types are of a peculiar construction, but can be cast as cheap as those ordinarily used. The composing sticks and other materials are also of a different construction, but not more costly. The machine, being so simple, it is not liable to get out of order, and not expensive to repair when it does.

So completely had the inventor planned the whole that the machine was built precisely according to the first draft, and required no alteration, but performed on the first trial equal to the expectations that had been formed of it. It may be called a perfect machine, and we can see nothing to prevent it from going into general use.—*Providence Journal.*

Black Paint.—A paper recently read before the London society of arts, of which extracts are given in the English papers, contains some information that will be interesting to ship owners and others. The author

Mr. L. Thompson, states that black paint is in general very injurious to the wood on which it is laid. He says that any one who will observe a ship that has been for some time in a tropical climate will see the proof. "it will be found that the wood round the fastenings is in a state of decay while the white work is as sound as ever; the planks that are painted black will be found split in all directions, while the frequent necessity of caulking a ship in that situation likewise adds to the common destruction; and I am fully persuaded that a piece of wood painted white will be preserved from perishing as long again if exposed to the weather, as a similar piece painted black, especially in a tropical climate." He adds:

"I have heard many men of considerable experience say, that black is good for nothing on wood, as it possesses no body to exclude the weather. This is indeed partly the case; but a far greater evil than this attends the use of black paint, which ought entirely to exclude its use on any work out of doors, viz: its property of absorbing heat. * * Wood having a black surface will imbibe a considerable more heat in the same temperature of climate, than if that surface was white; from which circumstance we may easily conclude that pores of wood of any nature will have a tendency to expand and rond in all directions, when exposed under such circumstances. The water, of course, being admitted, causes a gradual progressive decay, which must be imperceptibly increasing from every change of weather."

Two circumstances that had fallen under the writer's observation, are given in proof of this:

"The first was the state of H. M. sloop Ringdove, condemned by survey at Halifax, N. S. in the year 1828. This brig has been on the West India station for many years. On her being found defective and a survey called, the report was to the effect that the wood round all the fastenings was totally decayed in the wake of the black, while that in the wake of the white was as sound as ever. The next instance relates to H. M. ship Excellent, of 98 guns, (formerly the Boyne.) The ship is moored east and west, by bow and stearn moorings, consequently th estarboard side is always opposed to the effects of the sun, both in summer and winter. In this situation her sides were painted in the usual manner of a ship of war, viz: black and white, of which by far the greater part is black; this latter portion on the starboard side I found it impossible to keep tight; for, as often as one leak was apparently stopped, another broke out, and thus baffled the skill of all interested.

In the mean time, the side not exposed to the rays of the sun remained perfectly sound. I then suggested to Mr. Kennaway, the master caulker of H. M. dockyard at Portsmouth who had previously given the subject consideration, the advan tages likely to be derived from altering the color of the ship's side from black to white. Captain Hasting approved of the alteration, the ship was painted a light drab color where it was black before, upon which the leaks ceased, and she now has continued perfectly tight for more than twelve months; and indeed, I can confidently state, that the ship will last as long again in her present situation, as she had begun to shrink and split to an astonishing extent when the outside surface was black, which has entirely ceased since the color has been altered."—*New York Post.*

Wrought Iron Shafts.—One of the greatest improvements in steam navigation is the introduction of the wrought iron shaft, which is now generally, if not altogether, used in Great Britain. Of the multitude of boats running in the waters of the United States, we know of only one that has a

wrought iron shaft, and that one is the floating palace called the Burlington, Capt. Sherman's boat, on lake Champlain. This shaft was imported from Scotland. It is with us an almost every day occurrence to hear of the breaking of the shaft of some steamboat, and when this is the case it is generally followed by the breaking of other parts of the machinery, to the amount, frequently, of some thousands of dollars, and the detention of the boat. Under these circumstances, we rejoice to learn that the leading proprietors of steamboats in Canada have determined to introduce the wrought iron shafts; and we understand that the only reason why they have not been brought into use in this country was the want of machinery to make them. That difficulty no longer exists. Yesterday we accepted an invitation to visit the iron works of Mr. L. B. Ward, at the foot of 59th street, on the North river. Here we spent some time in seeing the process of manufacturing a shaft, which is twenty-three feet five inches long, and in the manufacturing of which six thousand pounds of iron have been used. The shaft will be finished in the course of the night, and will then weigh upwards of four thousand pounds. The material used is the best American iron, and in welding every care has been taken to make the shaft complete and perfect. We are told that steamboat machinery, equal to any in the favorite Britannic ships, can now be made in this city—perhaps at a little more expense than in England or Scotland, but it can be done, and well. Machinery is now making in New York for Russia and Spain. The trip hammer which we saw at work on the shaft, at Mr. Ward's, weighs thirteen thousand pounds, and is worked by a steam engine of thirty horse power. The shaft is not suffered to cool from Monday morning until Saturday night; two sets of workmen are employed, who relieve each other at suitable intervals.—*New York American.*

American Mechanics.—It is stated that a company in Trieste, Austria, have despatched an agent to buy the entire machinery of a flouring mill, and to take it over to Trieste. Some shipments of wheat having been made to the United States from Austria in 1836, '37, it was ascertained by those who sent it, that when it was ground up in this country, better flour and more in quantity was produced than could be obtained from the same quantity of wheat in Austria. The knowledge of this fact caused the mission of a special agent for the purpose above named. A New York paper says—.

The agent on his arrival in New York, contracted with the Lafayette Burr Stone company, at the corner of Robinson and Washington streets, to construct 8 run of mill-stones, of a sufficient size to turn out 500 barrels of flour per day. These 16 stones are now completed, and heve been shipped. The running gear and the working gear have all been made in this city, and the whole will cost about $15,000. A miller from Richmond has also been engaged to go out to Austria, and work the mill three years. A millwright also goes out to put up the mill. In short, this country furnishes every thing connected with it except the frame of the mill.

This movement is but the first of a series towards an extensive business to be done by the United States in the manufacture of mills and machinery for European nations. Already has this country sent out to France, England, Russia, Turkey, Austria and other European countries, frigates, steamships, sailing vessels of all kinds, locomotives, steam engines, cotton gins, printing presses, mill machines, and all kinds of improvements in every description of machinery; and Mr. Cochran has supplied the Pacha of Egypt with guns to carry on the war against the allied powers. We have steam frigates on the stocks for Spain, one for Russia, in our waters, print-

ing presses for the continent of Europe, just finishing at Hoe's foundry; many chambered cannon just finished for the Pacha by Cochran; rifles and guns of all kinds on the way to France; American cotton gins just finished, and put up by an American in Manchester; and in fact all sorts of machinery making, and to be made, for the old world, by the enterprising, industrious and ingenious artisans of the new world.

A Safety Beacon has been erected on the Goodwin Sands, by which it is hoped to avert the dreadful loss of life by shipwreck, so often occurring at that dangerous part of the British channel. It is thus described:

It consists of a column about forty feet above the level of the sea, having cleets and ropes attached to four of its sides, with holds for hands and feet. At the summit of the column is attached a gallery of hexagon form, made of trellis work, and capable of holding twenty persons at one time. Above the gallery, and in continuation of the column, is a flag-staff ten feet long, thus making the entire beacon fifty feet in height. The sides of the gallery are so constructed as to enable the persons in it to be covered in with sailcloth, which is reefed in and around it, and can be used at pleasure, as also an awning to pass over it which is fixed to the flag-staff, thus entirely protecting any unfortunate marriner who may seek shelter on the column from foul and tempestuous weather. A barrel of fresh water, together with a painted bag enclosing a flag of distress, is stationed on the gallery, and the words "hoist the flag," painted, in the languages of all nations, on boards stationed round the inner part of the gallery, so that the foreigner as well as the native seamen may be enabled to show a signal of distress, and obtain help from shore, which is about seven miles from the beacon.

American Copper.—We are gratified to learn from a late number of the Wisconsin Enquirer, that Messrs. W. Alvord and P. W. Thomas of New Baltimore in that territory, have met with complete success in their experiments on smelting copper ore. They constructed a very simple furnace which cost ten dollars, in which they smelted on the 28th of September last, 2,500 pounds of ore, from which they obtained nearly 700 pounds of good pig copper, pronounced, by competent judges, to be superior to the South American pig copper. The time occupied in procuring from the ore the above amount of copper, was only nine hours. Neither Mr. Alford nor Mr. Thomas had had any experience in the business of smelting, and the result is justly deemed a matter of great consequence to that Territory, which abounds in rich copper ore.

We import over three millions worth of copper annually, which we hope ere long to obtain from our own mines, while we export largely this valuable metal.

Collinsville Axe Manufactory.—These works, for extent and complete workmanship, have not a parallel in the States, nor in the world. The number of axes and hatchets manufactured when the works are in full operation, are about eight hundred daily. All the axes undergo the most rigid inspection and every one bears the stamp of "Collins & Co." In the excellency of the stock and complete finish, they have no where a superior.

The most curios part of the works is the press. This gigantic piece of machinery receives the heated iron from the bar, and with a few motions of its huge jaws, in the space of one minute, throws out the axe complete, except steeling. It is then passed to the hands of the forger, still glowing with heat, to receive the steel.

The welding in of the steel is very speedily performed, and made ready for the grinder.

The principal forging shop has twelve circular chimneys with 4 fires to

each. All these fires, together with the temperers' fires, and several others connected with the establishment are supplied with wind from a single bellows. This is very large and powerful; it occupies together with a large water wheel and machinery, an entire building. The wind is conveyed from the bellows in different directions, through large iron pipes under the ground, to the several shops and thence through smaller ones to the forges.

Any person wishing a quantity of axes of any particular pattern, can have them in one hour after the order; they will have passed through 12 classes of hands to be ready for delivery.—*Springfield Republican.*

Polytechnic Institution.—Two models of inventions, connected with the all absorbing subject of travelling by steam on land and water, have recently been deposited at the Polytechnic institution, in Regent street. One of these is a plan, devised by Dr. Spurgin, for preventing engines and carriages running off the rails, the greatest danger to which railway locomotion is exposed. The alteration proposed by the inventor appears to be at once simple, effective, and practicable. By elevating the line of a rail a sufficient height above the ground, room will be gained to permit a large portion of the body of the engine or carriage to go below the wheels on which they travel, being affixed to their sides instead of underneath. By this arrangement the centre of gravity will be much nearer the rail than it is at present, and a greater portion of the danger of top-heavy impetus be avoided, as it will be almost a physical impossibility for a train thus built to get off the rails. This improvement ought to be looked to immediately, as if effectual, it is certainly practicable. The other model exhibits a scientific alteration in the common paddle wheel of a steamboat, and, assuming that inventive genius should direct its energies towards the improvement of this always objectionable means of propulsion, instead of assisting to discover a new perfect method, we should say that great credit is due to the inventor, Mr. Stevens, of Woodford. His plan is this:—Every float is the segment of a sector, and each coincides with the other; in fact, it is like nothing so much as a common ventilator in a window frame or door. The inventor states that its construction is founded strictly on theory, and that it possesses the greatest propelling effect, without any backwater or vibratory motion. The institution closes for six weeks on Saturday, in order to allow time for considerable additions and improvements.

The Thames Tunnel.—The famous Thames tunnel, as is well known, is now near completion. The mode of egress, for foot passengers, is to be by a spiral staircase. The carriage way is to be spiral, and two hundred feet in diameter. The gradients of the road will be about one foot in twenty-five, forming an inclination by no means inconveniently steep.

The railroad between Boston and Salem has conveyed a million of persons in the year it has been open, without injury to a single traveller.

Another Iron Steamboat.—The Louisville Gazette notices the construction of an iron steamboat in that city, which was launched a few weeks since. The experiment made by the projectors of the Valley Forge has been entirely successful. Its bottom is nearly, if not quite, proof against snags, and escapes injury from bars and shallows altogether. Success attend this new enterprise.

Apropos—The Britania has taken to Havre, from London, an iron steamboat in five hundred and seventy-two pieces. This vessel, which is intended for the Lake of Geneva, will be one hundred and thirty-three feet long, and the materials are to be transported thither forthwith.